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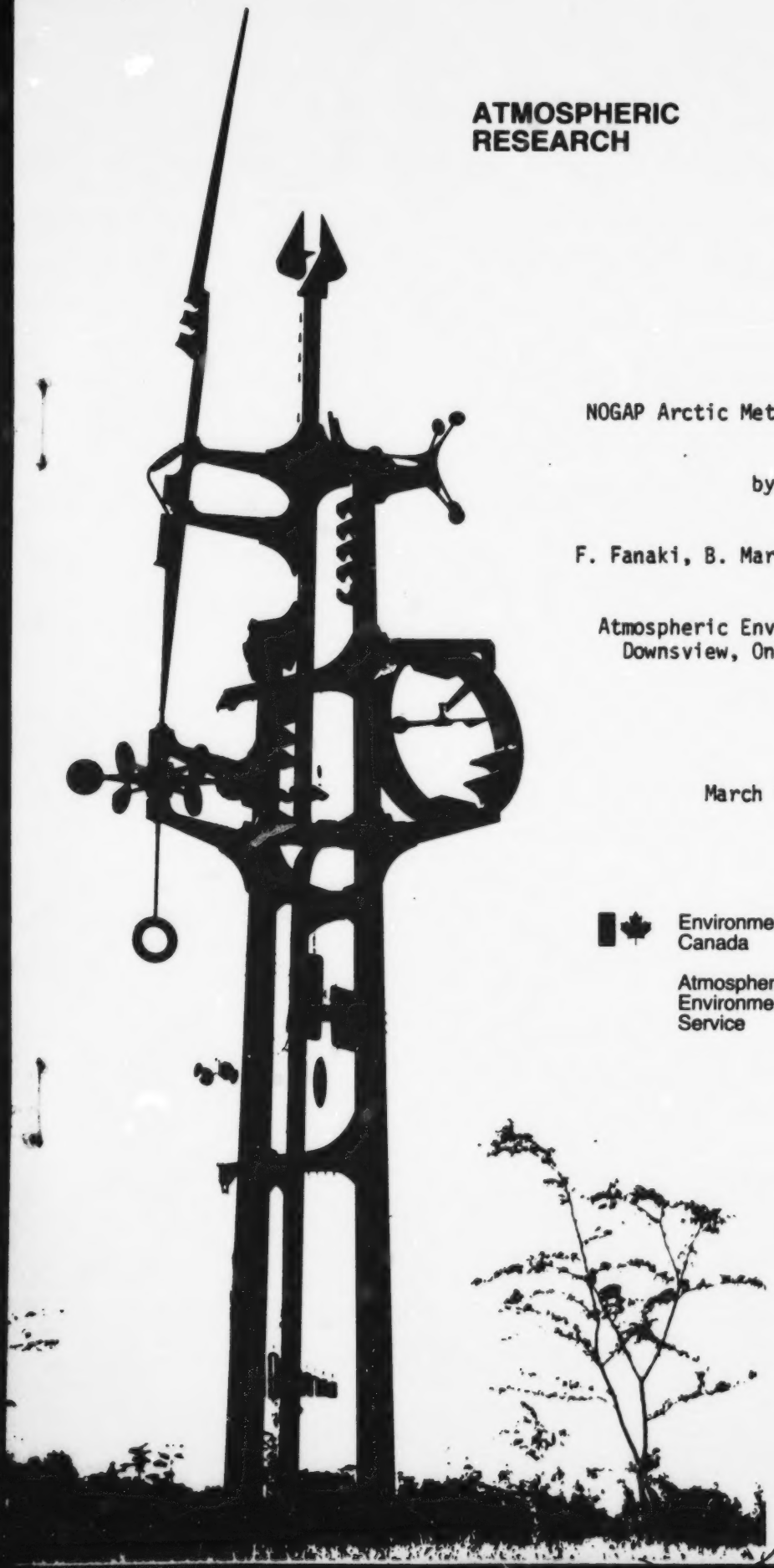
ATMOSPHERIC RESEARCH

RECHERCHE ATMOSPHÉRIQUE



NOGAP Arctic Meteorological Tower

by

F. Fanaki, B. Martin and J. Markes

Atmospheric Environment Service
Downsview, Ontario, Canada

March 1986

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ABSTRACT

Six temperature, wind speed and wind direction sensors were installed at various heights on the CBC 100 metre television tower in Inuvik, N.W.T. In addition, a HUMICAP, to measure the relative humidity at 2.5 m and 15 m levels, and two Eppley pyranometers, to measure Albedo at 1 m height, were installed. The purpose of this project is to gather detailed information to form a data base of atmospheric parameters. The data are averaged every 10 minutes and stored on tap at the AS6, AES computer ready for use upon command.

This report describes in detail the site, tower and the installation of the sensors. The characteristics of the sensors are also examined. A sample of the collected data is presented in this report.

Acknowledgements

The authors are appreciative of the funds and support provided by the Northern Oil and Gas Action Program (NOGAP) to carry out this study. Particular thanks are due to the Economic Advisor Mr. W. Brackel and to those of the Service NOGAP coordinators.

We wish to thank the CBC Northern Service for permitting us to use the Inuvik tower, without which our study would have never materialized; the CBC Inuvik technical staff, in particular Mr. Jay Sparks and Mr. Phil Russell for their valuable assistance and support. The authors also wish to thank Mr. Magnus Burke EPS Inuvik for his assistance; and Dr. David Sherstone, Inuvik Resources Laboratory, for his invaluable advice.

Introduction

There is considerable uncertainty in our knowledge of the meteorological parameters and climatological conditions that promote an air pollution episode in the Arctic. This uncertainty stems from the sparsity of detailed meteorological data and the unfamiliarity of the Arctic topography. In addition the Arctic is remote and cold. Mean daily temperatures reach -30°C and on some occasions may drop to -50°C.

Most of the meteorological observations at Arctic sites are surface measurements (10 m level). The available surface observations are biased. There is a tendency to choose surface observation sites among relatively populated areas that may have artificial environments (e.g. airports and oil drilling sites). This data, however, should not be considered unreliable because of its unrepresentative exposure; the data are useful in describing general trends of meteorological variables.

In the Arctic there are scattered aerological stations that provide profiles of temperature, windspeed and humidity twice per day. These data are not detailed enough to provide statistical information necessary to define stability conditions at any given time. In addition radiation inversions occur frequently in the Arctic and persist for relatively long periods especially during the winter (e.g. Munn et al 1970). Any assessment of the environmental problem during that period depends strongly on the assumptions made regarding the atmospheric conditions.

The Northern Oil and Gas Action Plan (NOGAP) established a program in the Beaufort Sea Region with the objective of assessing the environmental impact of air pollutant emissions associated with the hydrocarbon development in this area of the Arctic. This objective is met by the following sub-objectives:

1. Development of a data base of atmospheric parameters related to air quality,
2. Conducting a series of short duration field studies to supplement the data base and to provide background information with regard to air quality models,
3. Development and evaluation of air quality models for air quality assessment with specific application to the hydrocarbon development in the Beaufort Region,

During the first year of the NOGAP program, the efforts of Project C.1y (Beaufort Sea Air Quality) were concentrated on the first and the second sub-objectives. This report deals only with the first sub-objective. It describes the various components of this study as well as presents a discussion on the data obtained to date.

II Background

With regards to sub-objective #1, it was felt that a tall meteorological tower (100 meters) should be erected in the primary study area, and be instrumented so as to provide continuous information on vertical profiles of

temperature and wind. Also plans were made to integrate solar radiation and relative humidity sensors. These measurements would then form the meteorological data base necessary to provide information in the development of air quality models and for indentifying atmospheric features unique to this region of the Arctic.

During the early stages of the program, it became apparent that problems could be encountered in the construction of a tall tower in the study area (lack of funds and time). To bypass these problems, a survey was made of existing towers in the Mackenzie Delta and Beaufort coastal areas. Four towers were discovered, one operated by the Canadian Broadcasting Corporation (CBC) - Northern Services in Inuvik, and three by Dome Petroleum in their Beaufort Sea operation. Both companies were contacted and gave permission for air quality staff to visit their facilities and evaluate them for possible utilization as a platform for the meteorological and air quality sensors.

The Inuvik CBC tower proved most suitable. Also, Inuvik has a high frequency of periods of light winds and stable conditions which are critical from a pollutant dispersion point of view. Negotiations with CBC - Northern Services in Ottawa, went well. After acceptance of an engineering consultants report, indicating the tower in Inuvik was suitably stressed to take the added weight of the meteorological equipment, a lease agreement was signed between AES and CBC at a cost of $6,400 per year. The cost also includes operation and first level maintenance on the data storage mediums by CBC on-site technical staff.

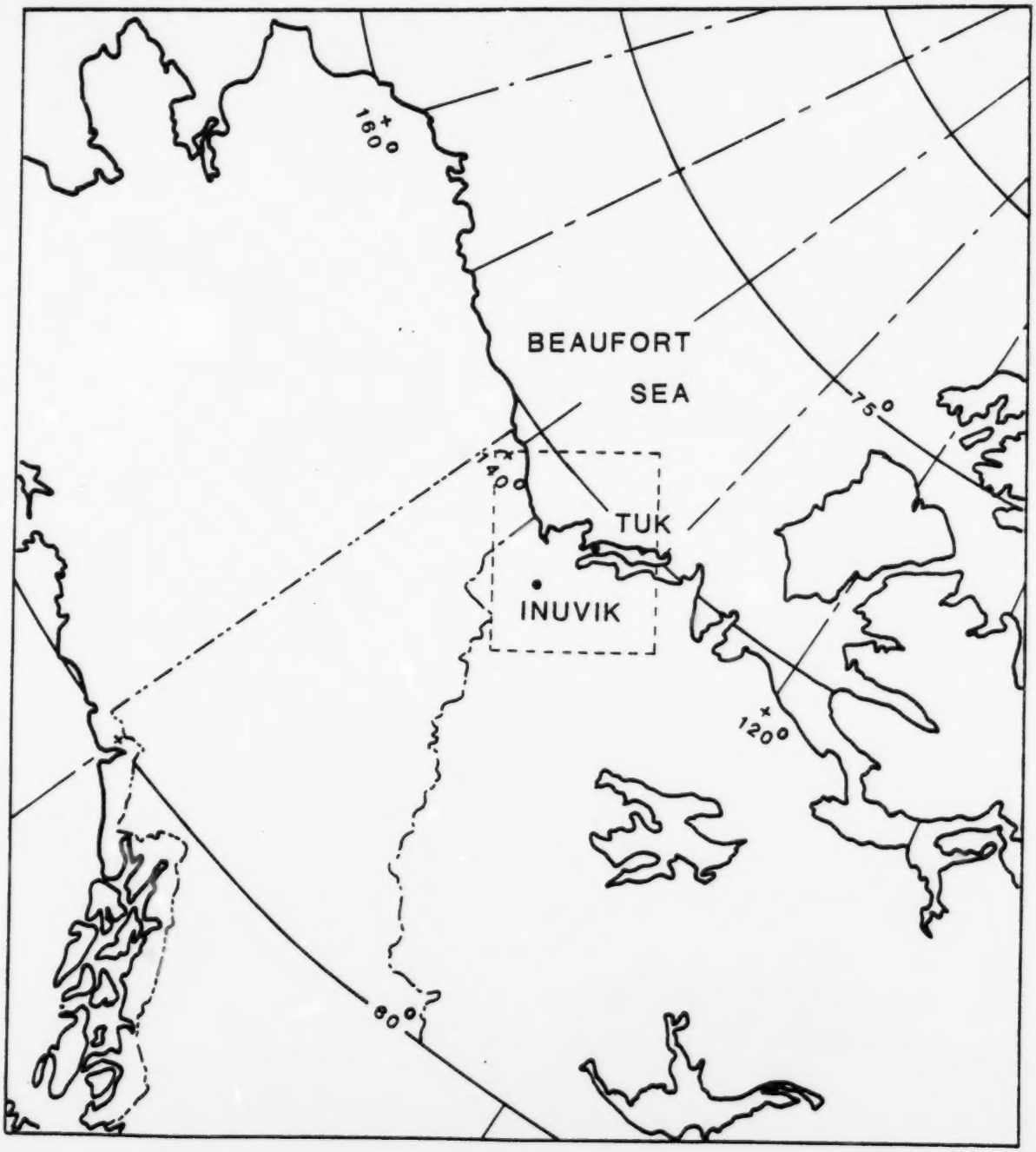
III Site and Tower Description

Inuvik lies within the northernmost reaches of the treeline, and has a combined arctic and sub-arctic environment. It is located on the east side of the East Channel of the Mackenzie River Delta, 100 km south of the Beaufort Sea. Figure 1 shows the location of Inuvik and its surroundings.

The Mackenzie River Delta, which is the twelfth largest in the world, extends approximately 240 km from its head, northwards to the Beaufort Sea. At its widest point, it is approximately 160 km across. The Delta itself is bounded by the Richardson Mountains on the west and the Caribou hills on the east. As one travels northwards, the Caribou hills give way to rolling uplands. The northeastern end of the Delta is capped with the mass of Richards Island - an island comprised of older sedimentary formations with a more rolling topography than that of a modern delta.

Looking westwards from Inuvik one sees the Richardson mountains (approximately 80 km away). These bare mountains reach up to 1200 meters above sea level.

To the north of Inuvik, the Caribou Hills stretch northwestwards for some 50 kilometers, paralleling the east channel of the Mackenzie Delta. These hills attain a maximum elevation of 200 meters. The Caribou Hills break into tundra covered barren lands (intersparsed with many small lakes) to the north, and sparsely wooded lichen forests to the south. These forested areas can be broken into two groups. The well-drained benchlands, where the permafrost table is low support white spruce of sawlog size, however, some trees do attain a height of 20 meters. Tree growths on the alluvium, however, are poor



PROJECT C-19 AREA OF OPERATION

FIGURE 1: Map of the NOGAP study area showing the location of Inuvik.

with scrubby types composed mainly of willow, alder, stunted white and black spruce.

The tower is situated approximately 1.5 km east of the Inuvik town centre at an elevation of 80 m (ASL). Figure 2 (a, b) gives a visual display of the tower site and the surrounding topography. The tower is of a triangular design, with the tower legs 1.22 m apart. The height is 103.7 m and is capped with a 6 m antenna. Figure 3 shows a photograph of the tower during the winter. Microwave dishes are mounted at the top of the tower, limiting its usefulness to the NOGAP program to the 91.5 m elevation and lower.

At the base of the tower there are three low buildings (2 m in height). Figure 4 shows a photograph of the base of the tower together with the associated buildings. The close proximity of these buildings to the tower makes use of the lowest 10 m unsuitable for meteorological measurements. To offset this, a standard 10 m meteorological tower was erected 73 m east of the main tower (Figure 5). This tower is at an elevation of 77 m (ASL).

IV Instrumentation

The meteorological variables that were selected for this study are tabulated in Table I. There are numerous meteorological sensors available for measuring these variables. The selection of the sensors to be used in the Arctic should be made according to the following:

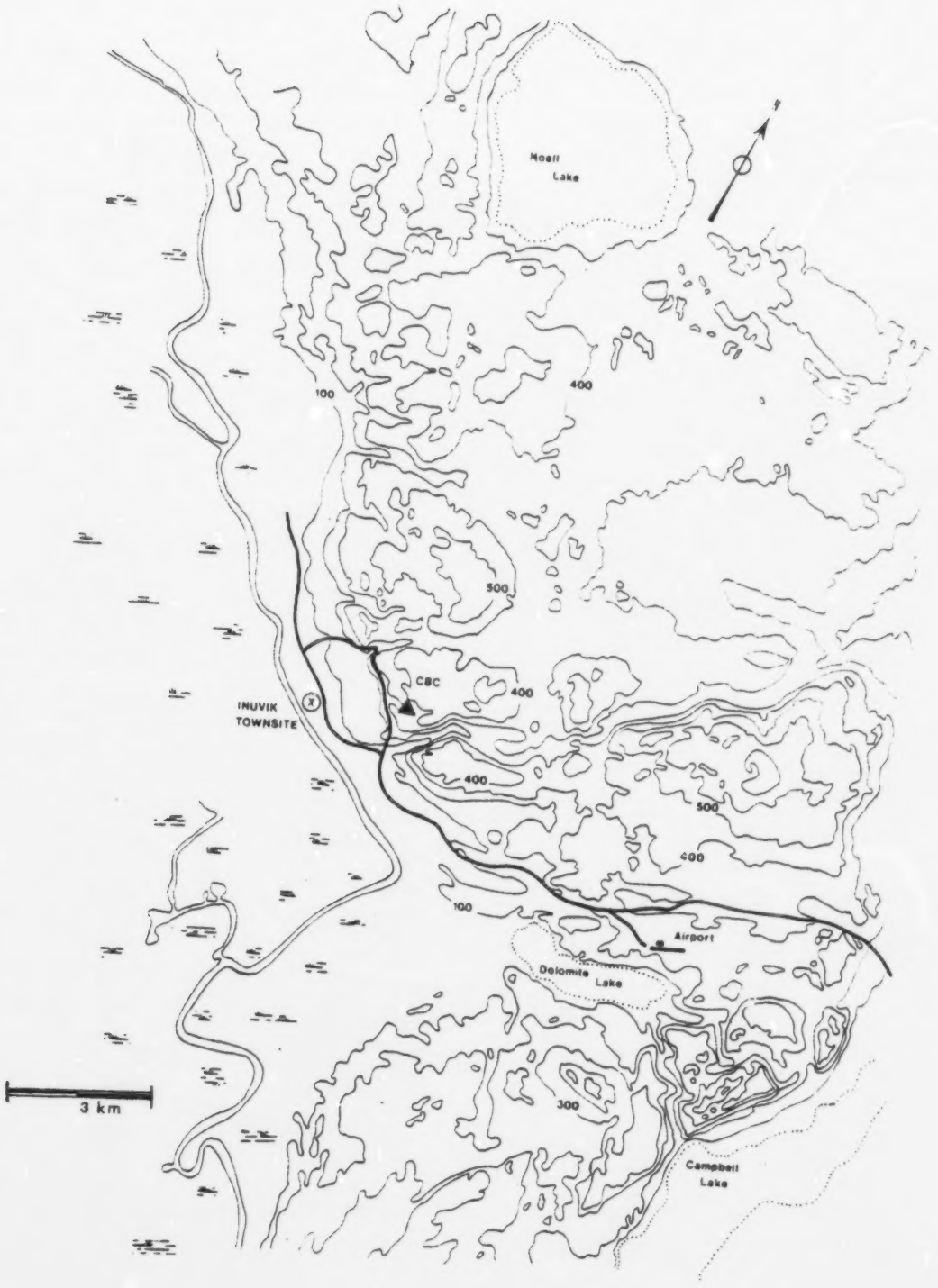


FIGURE 2a: Topographical Features of Inuvik and vicinity.

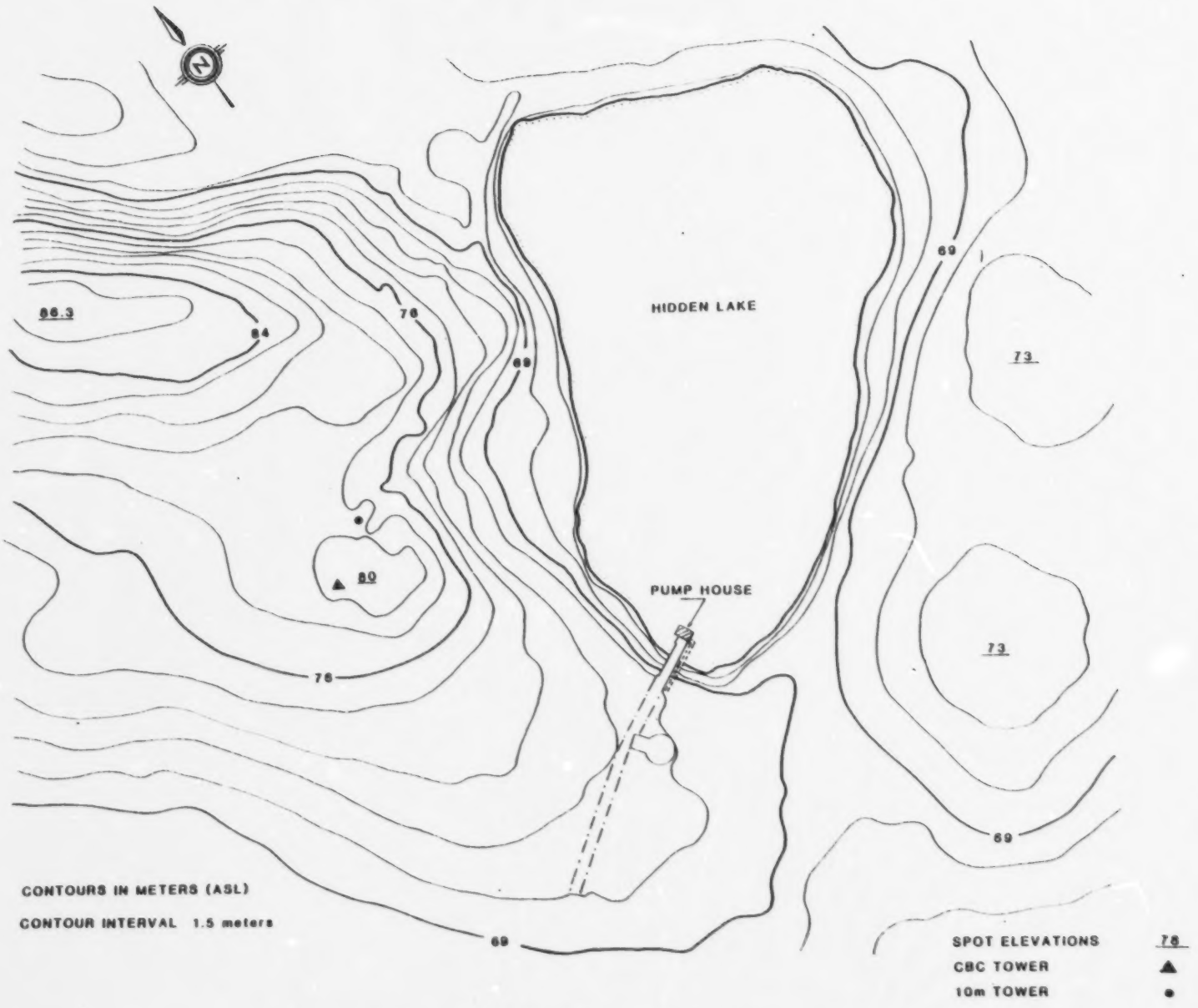


FIGURE 2b: Topography of the Tower site.

FIGURE 3: CBC Inuvik Meteorological Tower.

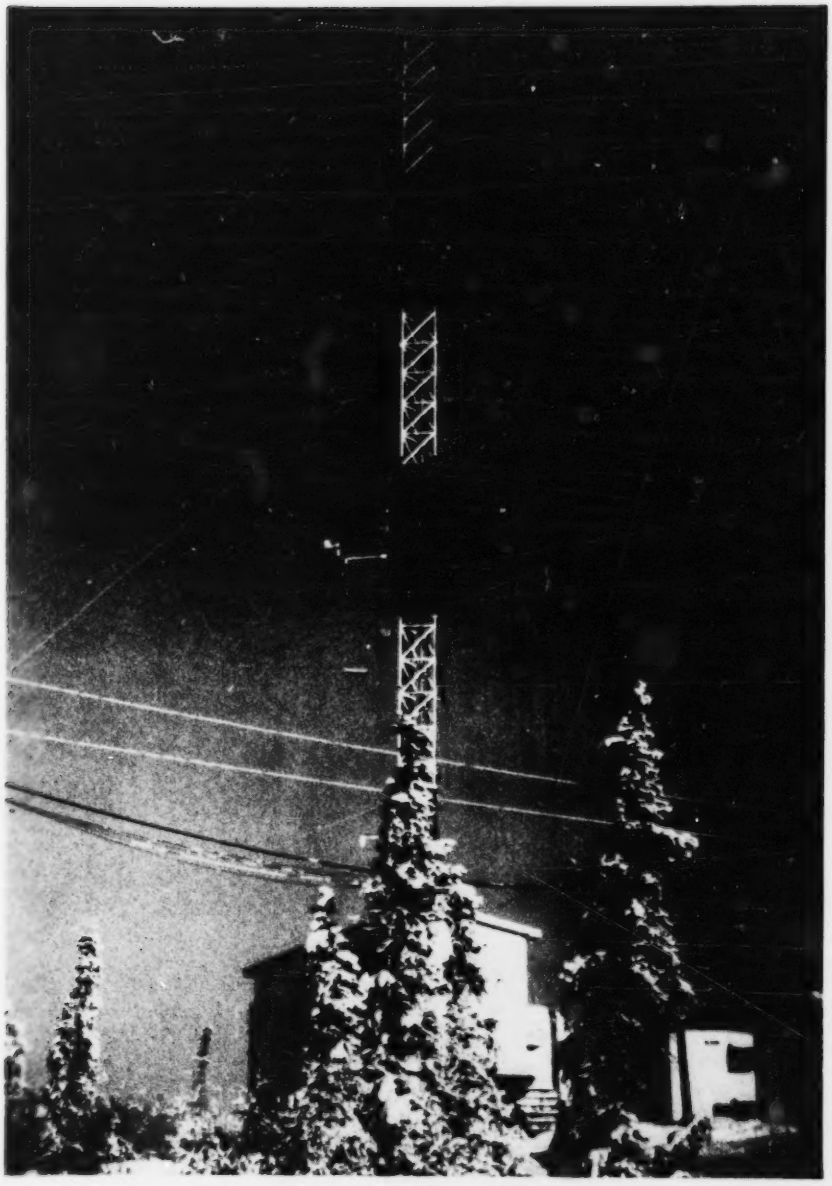


FIGURE 4: CBC Tower Buildings.

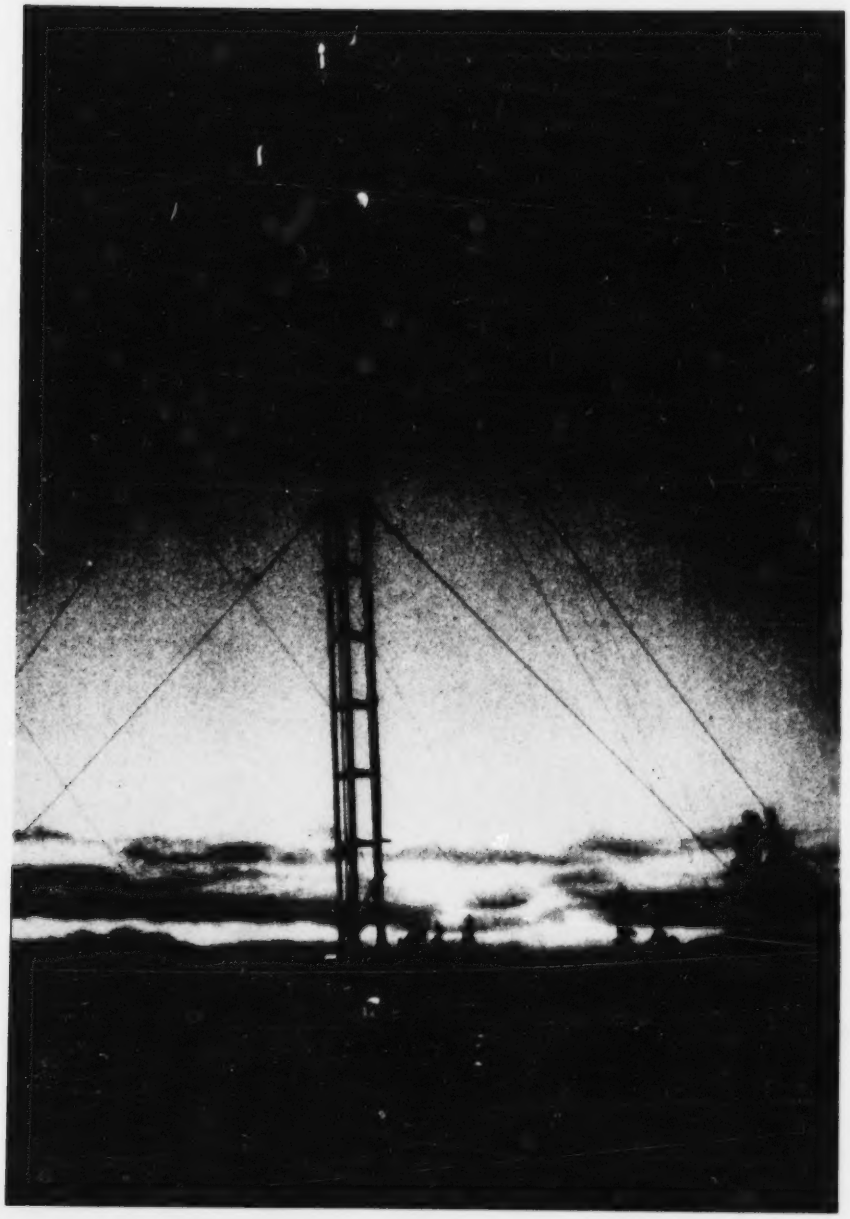


FIGURE 5: 10m Meteorological Tower.

Table I. Meteorological Variable under Study for the NOGAP Program C.19

Variable	Symbol	Units
Mean horizontal wind speed	U	m/s
Mean wind azimuth direction from true North	D	degree
Mean vector wind speed	V	m/s
Mean Vector Wind azimuth direction	DV	degree
Mean air temperature	T	°C
Relative humidity	RH	
Standard deviation of wind speed	SU	m/s
Standard deviation of wind direction	SD	degree
Standard deviation of vector wind speed	SV	m/s
Standard deviation of temperature	ST	°C
Incident solar radiation	K↓	watt m^{-2}
Reflected solar radiation	K↑	watt m^{-2}

a - the sensor should be sensitive but rugged.

b - since the measurements are to be made for a long period (3-5 years) the sensor should be free from maintenance.

Two types of sensors that come to mind and qualify for this work are the Bendix model 120 Aerovane for windspeed and wind direction measurements and the Rosemount Platinum Resistance thermometer/linear bridge combination for the temperature measurements. The task of choosing a sensor to measure the relative humidity in a very cold environment was difficult. The Humidity and Temperature Indicator Type HM132 was chosen for this study. For radiation measurements the Eppley pyranometer was chosen.

Cables connecting the sensors to the CR-7 are shielded to prevent RF interference, as well as being constructed with a mylar coating that is specified to maintain flexibility in a temperature regime between minus 65°C to plus 125°C.

Waterproof junction boxes of the Crouse Hinds W.J.B. type were used on the tower installation. The connectors for the junction box were of the Crouse Hinds C.C.B. type.

In order to avoid the downwash from the tower, temperature and wind sensors are mounted on 4 m booms. Care was taken to have the wind sensor extend at least four tower diameters beyond the face of the tower. Figure 6 shows a photograph of a typical boom with its associated equipment. These booms extend into the northwest quadrant, along the northwest face of the tower (the other two tower faces were occupied with electrical conduit and cable). A tower shadowing effect will occur with winds blowing out of the southeast quadrant, however, climate records over a 20 year span show that

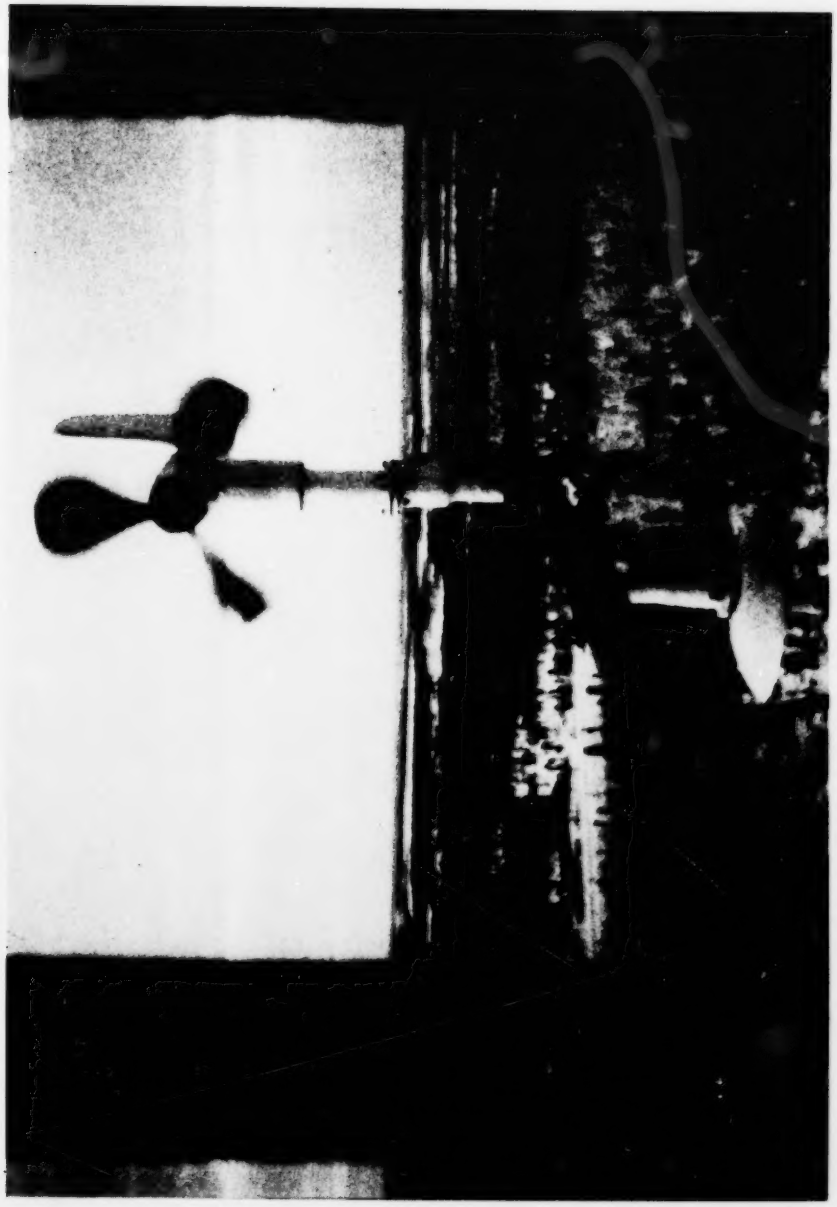


FIGURE 6: Tower boom with its associated Meteorological sensors.

Inuvik has a relatively low percentage frequency of wind directions from SSE to ESE (Fig. 7).

The main CBC tower was instrumented at 5 levels - 20, 40, 60, 80 and 91 meters. Each level contains a Bendix aerovane and aspirated Rosemount platinum bulb thermometer (Fig. 3). In addition Humicap humidity sensors were installed at the 25 meter and the 15 meter levels of the tower.

The 10 meter tower was outfitted with a Bendix aerovane and an aspirated Rosemount Platinum Bulb RTD at the 10 meter level, as well as Eppley R1 and R2 solar radiation sensors at the 1 meter level (Fig. 5).

All sensors are connected to a Campbell Scientific CR-7 data logger (with expanded memory), located in the CBC transmitter building.

Wind Sensors

The Bendix Model 120 Aerovane were brought in from the Research Station tower in Woodbridge, Ontario. They were refurbished and new replacement parts were installed. General condition of the sensors were good considering that they have been exposed to the elements for over 6 years. Specifications of the Bendix aerovane are displayed in Table II.

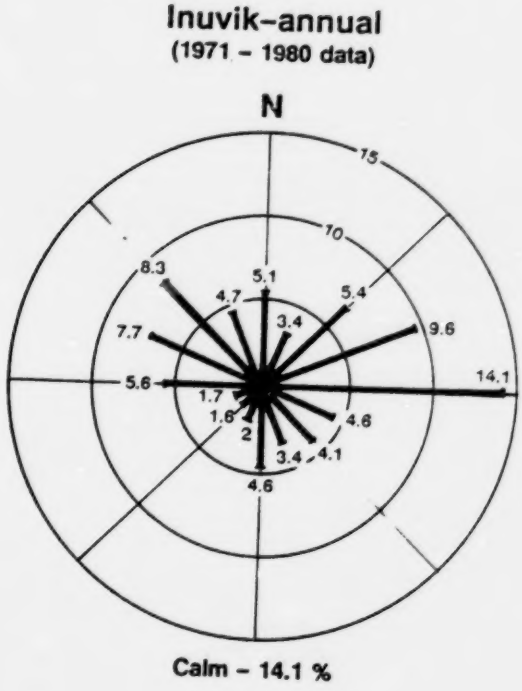


FIGURE 7: Inuvik annual wind rose.

Table II. Specifications of Bendix Aerovane Model 120

Parameter	Specification
Size	.56 m (22") long x .56 m (22") high
Rotor	3 bladed, .3 m (12") diameter
Weight	5.9 Kg (13 lb)
Accuracy	Wind Speed Range Error 0-4.5 ms^{-1} (0-10 mih^{-1}) ± .2 ms^{-1} (± .5 mih^{-1}) 4.5-89.4 ms^{-1} (10-200 mih^{-1}) ± .45 ms^{-1} (1 mih^{-1}) Wind Direction ± 2° complete Range
Wind Distance Speed Constant	4.6 m (15 ft)
Wind Direction Distance Constant	10.4 m (34 ft)
Wind Speed Output	1 VDC for 4.23 ms^{-1}

Each sensor was tested and calibrated using the AES wind tunnel. Figure 8 is a photograph showing the AES wind tunnel with its associated equipment. The aerovane was placed at the centre of the test section of the tunnel with the aerovane propeller's plane perpendicular to the tunnel's flow streamline. The tunnel calibrated pitot speed probe was placed as close as possible to the aerovane. During calibration the tunnel was allowed to vary its speed from 2 to 19 m/s and the output aerovane voltage was monitored during each change of the tunnel speed. The results of the calibration is displayed in Table III and plotted in Fig. 9 (a,b). For eacn aerovane the calibration data was fitted by eye to the straight line

$$U = mV + b \qquad (1)$$

where U is the wind speed, V is the output voltage, m is the slope of the line and b is the line interception (Table IV). b represents the starting speed of each aerovane, ranges from 0.2 to 0.5 m/s. b is due to the friction of the aerovane's bearing system.

According to the manufacturer, the electrical output of the Aerovane into a 1150 Ω load is 0.0656 volts DC per km/h. The calibration is also linear with m equal to 4.23 m/s/volt and b = 0. By examining Table IV m agrees well with the manufacturer's calibration.

The response of the Aerovane to winds not perpendicular to tne plane of the propeller was examined by Teunissen (1986) using the AES wind tunnel. A typical Aerovane was pitched at various angles (ψ) (Fig. 10) at two constant

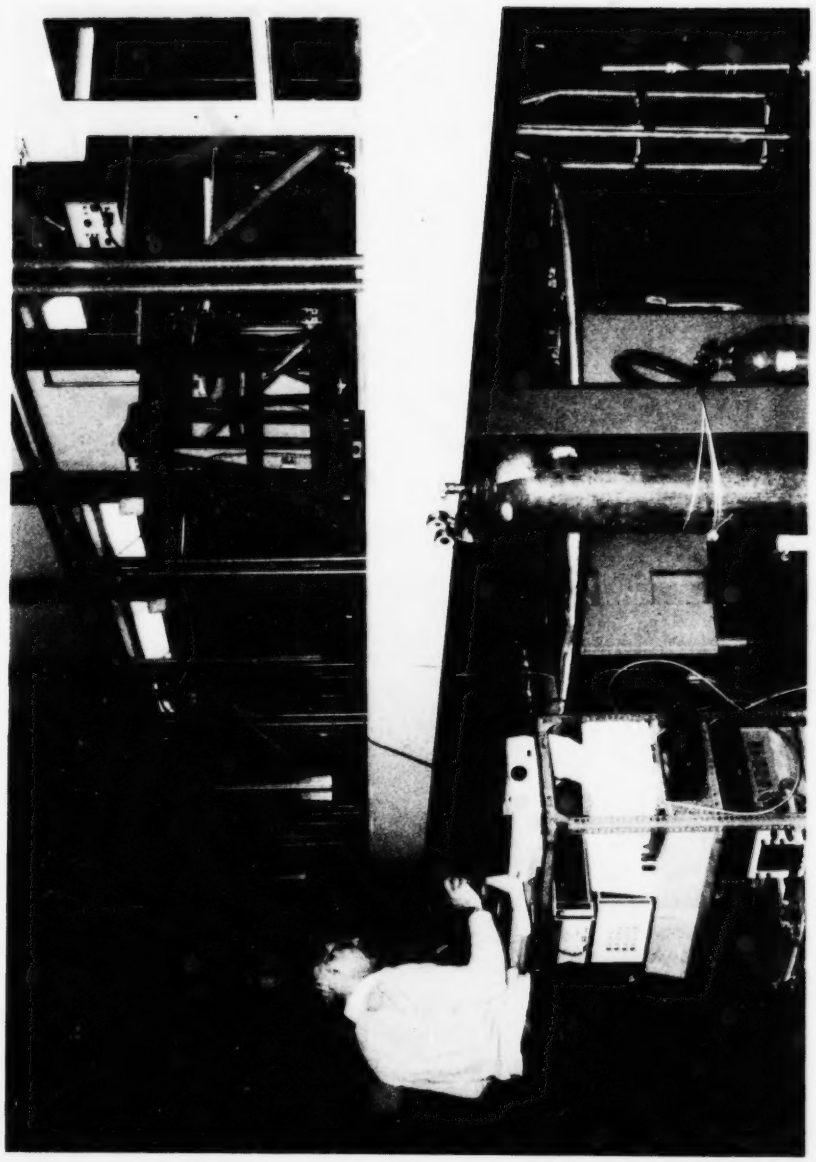


FIGURE 8: AES wind tunnel for the Bendix Aerovane calibration.

Table III. Aerovane Voltage Output as a Function of Wind Speed

Aerovane Serial Number	Elevation (m)	Output Voltage (volt)	Wind Speed (ms^{-1})
5278	spare	0.45	2.16
		0.94	4.21
		1.42	6.25
		1.92	8.41
		2.40	10.51
		2.89	12.59
		3.38	14.67
		3.87	16.74
		4.37	18.87
		0.52	2.31
5235	10	0.45	2.21
		0.96	4.21
		1.47	6.29
		1.99	8.44
		2.48	10.50
		3.00	12.60
		3.49	14.63
		4.00	16.72
		4.51	18.82
		0.54	2.43
4786	20	0.40	2.16
		0.93	4.21
		1.94	6.26
		2.43	8.42
		2.92	12.57
		3.42	14.65
		3.91	16.69
		4.42	18.90
		0.39	2.12
4785	40	0.43	2.13
		0.44	2.17
		1.45	6.21
		0.43	2.13
		0.94	4.19
		1.45	6.22
		1.98	8.40
		2.50	10.53
		3.00	12.58
		3.41	14.64
		4.00	16.65
		4.54	18.91
		0.42	2.12

Aerovane Serial Number	Elevation (m)	Output Voltage (volt)	Wind Speed (ms^{-1})
5280	60	0.44	2.18
		0.92	4.21
		1.40	6.26
		1.89	8.44
		2.35	10.47
		2.83	12.54
		3.29	14.57
		3.80	16.78
		4.27	18.84
		0.50	2.29
5277	80	0.53	2.35
		0.95	4.20
		1.45	6.31
		1.95	8.40
		2.46	10.56
		2.94	12.58
		3.43	14.62
		3.95	16.78
		4.45	18.87
		0.79	3.38
4784	91	0.44	2.16
		0.96	4.20
		1.46	6.26
		1.98	8.44
		2.49	10.60
		2.97	12.57
		3.48	14.66
		3.98	16.73
		4.49	18.83
		0.44	2.16

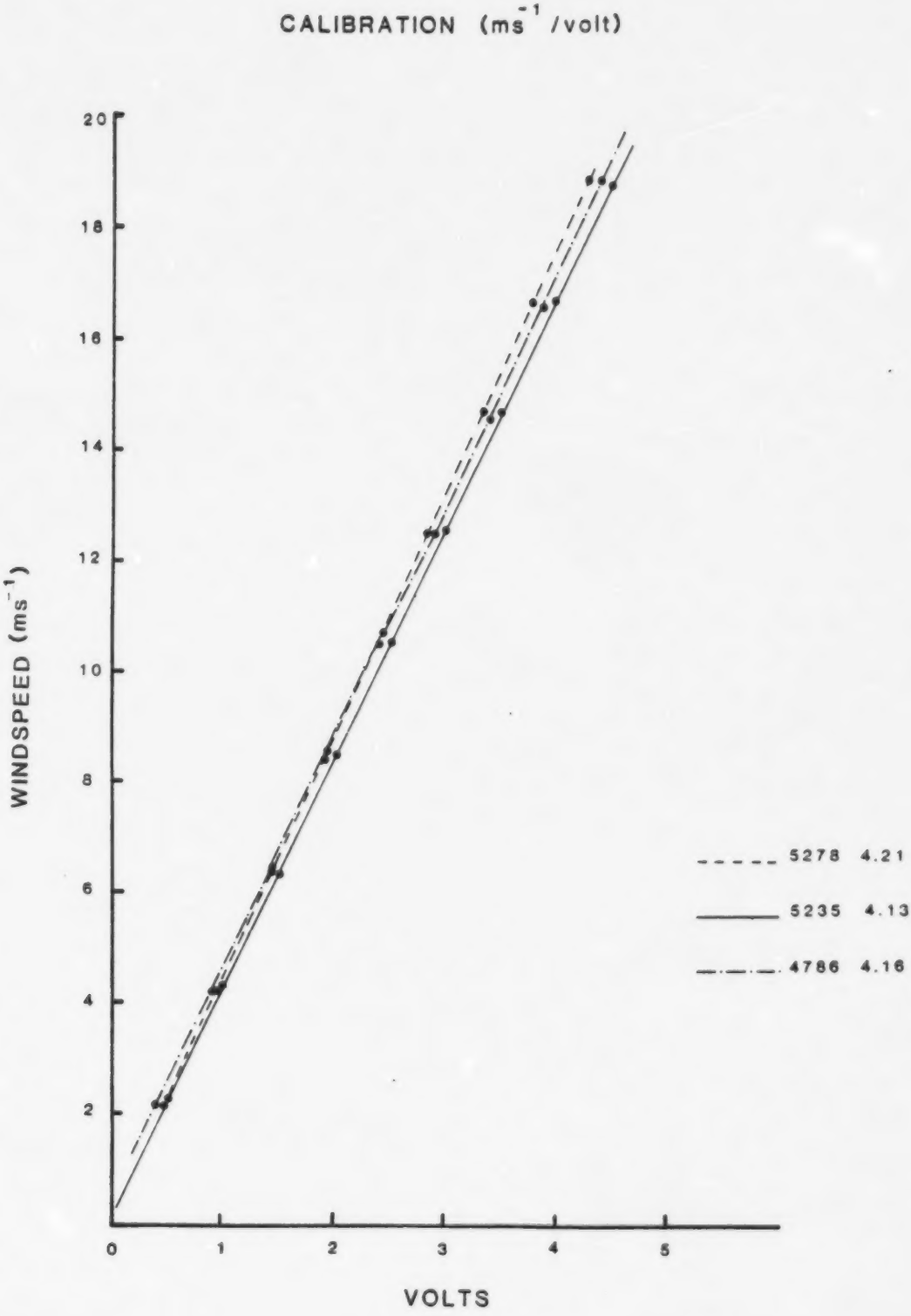
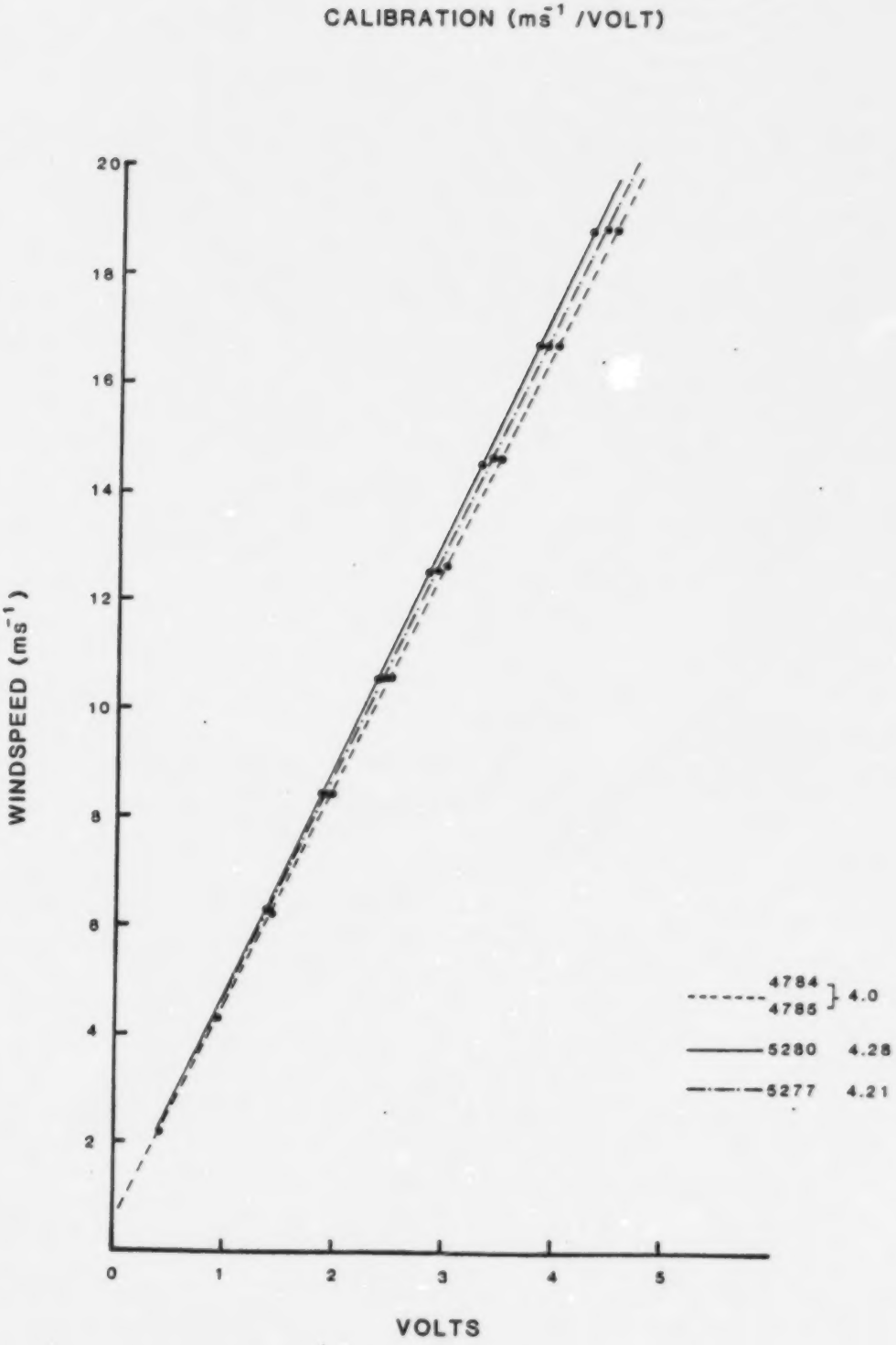


FIGURE 9(a): Output voltage as a function of wind speed for Inuvik aerovane.



FUGYRE 9(b): Output voltage as a function of wind speed for Inuvik aerovane.

Table IV. Calibration Parameters for the Inuvik Tower Aerovane Bendix Anemometer Model 120

Aerovane Serial Number	Aerovane Elevation (m)	m	b
5235	10	4.13	+0.2
4786	20	4.16	+0.4
4785	40	4.00	+0.5
5280	60	4.28	+0.4
5277	80	4.21	+0.4
4784	100	4.00	+0.5
5278	spare	4.21	+2

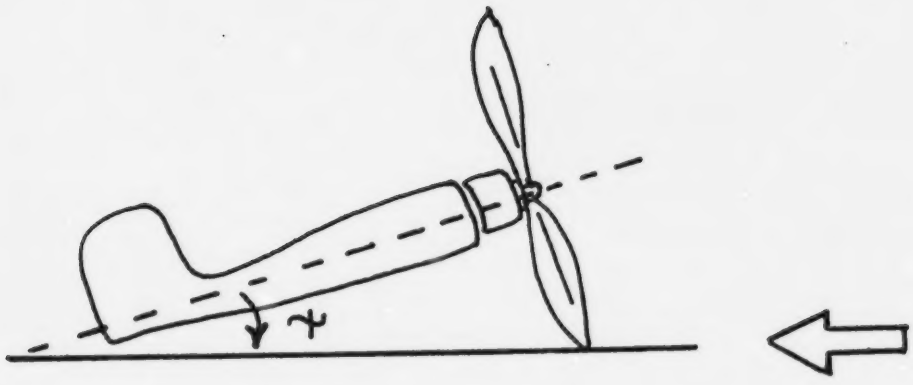


FIGURE 10: Elevation angle of the Bendix aerovane with respect to the flow.

flow speeds (3.2 and 15.2 m/s). The output voltage for each angle was monitored. The ratio of V (ψ)to voltage output for ψ = 0 (V(0)) is plotted as a function of the elevation angle ψ in Fig. 11. For comparison purposes the cosine response of the Aerovane was also plotted in the same figure. It will be noted at both wind speed the Aerovane response is less than the cosine response. The decrease is also a function of the wind speed, indicating a dependence on the Reynolds number. It is recommended then that the Aerovane should not be used in an environment where large values of ψ ($>10°$) may occur unless corrections are made. Such cases are not expected to occur frequently at the tower site in Inuvik.

A temperature test was carried out on the Bendix Aerovane where the sensor was cooled from 23°C to -27°C. The sensor was exposed to the cold temperature for 86.5 hr. Using a torque watch the sensor torque was examined before and after exposure to the cold temperature. Table V displays the result of the test. It will be noted the effect of lowering the temperature is negligible.

Temperature Sensor

The platinum resistance Rosemount Model 78-0039-0007 together with the Linear Bridge Model 414L were used to instrument the tower for temperature measurements. Table VI displays the specification of the sensor. The resistance element of the sensor is made out of platinum for its stability and having a linear resistance-temperature relationship. The probe is standardized by the adoption of the International Resistance vs. Temperature curve with an alpha of 0.00385 ohms/ohm/°C. The resistance elements of the sensor, not including the leadwire resistance, have 80.32 Ω at -50°C,

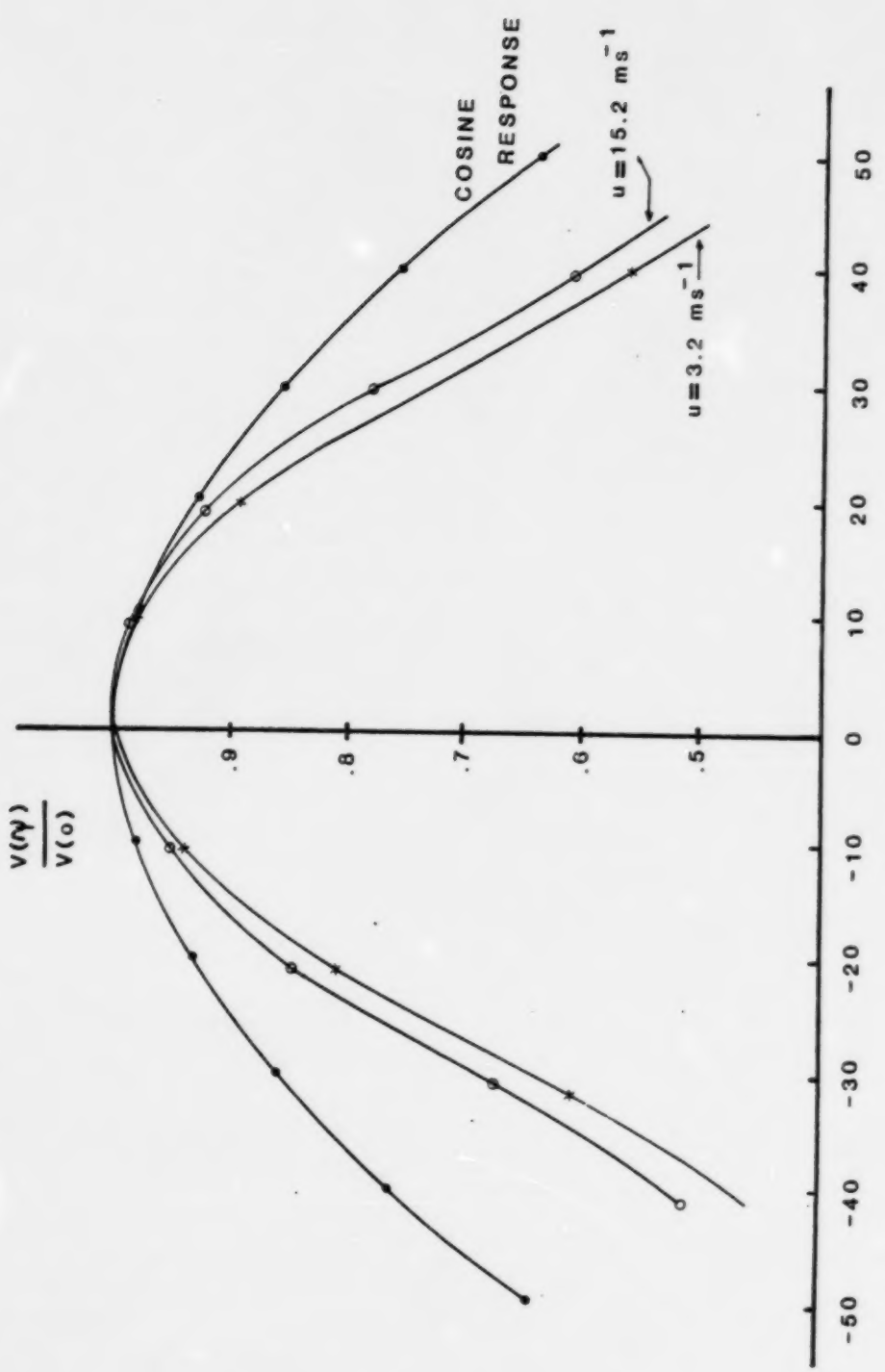


FIGURE 11: Elevation angle response of Bendix aerovane.

Table V. Bendix Aerovane Temperature Test

Item	Temperature	Exposure Time	Propeller Torque Range (gm/cm)
Aerovane 1	23°C	1 day	3.3 - 6.1
	-27°C	3.6 days	3.3 - 5.9
Aerovane 2	23°C	1 day	3.3 - 3.9
	-27°C	3.6 days	3.3 - 4.9

Table VI. Specification of Platinum Resistance

Rosemount Temperature Sensor

Parameter	Specification	
Temperature Range	-100°C to +660°C	
Accuracy	Temperature	Accuracy (°C)
	-100	±0.49
	0	±0.26
	100	±0.53
	300	±1.41
	400	±1.88
Repeatability	0.25%	
Stability	0.2%	
Time Constant	<5.5 S	

100Ω at 0°C and 119.4 Ω at +50°C. Each sensor is connected to a linear bridge Model 414L (accuracy ±0.1% of span). The bridge is matched to the resistance of the probe and used to determine the temperature. The bridge converts the resistance into a voltage output proportional to the air temperature. The output is zero millivolts at zero degrees and the slope is one mV per degree with an accuracy, according to the manufacturer, equal to ±35°F. In order to examine the capabilities of the sensor-bridge combination, all the temperature probes were calibrated in the AES Temperature calibration Laboratory. Since several tens of meters of leadwire will be used between the temperature probe on the tower and the data logger (at the base of the tower) it is felt that the calibration should be made with the sensor connected to the leadwire. In this way, the added resistance of the lengthy cable will be taken into consideration . Each temperature unit was calibrated by immersing the temperature probe in a constant temperature bath which was electrically heated to an accuracy of ±0.01°C. Fig. 12 shows a photograph of the calibration system with its associated equipment. The temperature bath was allowed to vary from -45°C to +40°C and was monitored by an independent temperature sensor. For each temperature change the sensor-bridge output was measured. The result of the calibration is displayed in Table VII. The result is shown in terms of the temperature difference between the actual temperature of the bath (T) and the temperature of the tower sensor with its associated bridge and cable (T_S). It can be seen from the Table that all the sensors underestimate the actual temperature. One sensor (88384) underestimated the actual temperature by as much as +0.3°C. However, the remainder of the sensors underestimate by 0.15°C. These values could be tolerated for this study. Overall the sensor-bridge combination is reasonably sensitive and accurate for the NOGAP study.

FIGURE 12: AES temperature calibration system and its associated equipment.

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TABLE VII. Calibration of 6 Rosemount Platinum Sensors

INSTRUMENT CALIBRATION UNIT
Test Results

PROJECT

SUBJECT Calibration of Six Rosemount Platinum Sensors

DATE Oct. 4, 1984

BY N.P. Rochacewich

Reference H.P. Quartz Therm.	(-45°C) -49°F	-40°C -40°F	-30°C -22°F	-20°C - 4°F	-10°C 14°F	0°C 32°F	10°C 50°F	20°C 68°F	30°C 86°F	40°C 104°F
Sensor s/n										
3717	-49.15	-40.13	-22.14	-4.12	13.86	31.83	49.78	67.77	85.70	103.72
3741	-49.20	-40.18	-22.19	-4.17	13.80	31.79	49.73	67.72	85.69	103.68
3760	-49.24	-40.22	-22.22	-4.19	13.80	31.80	49.73	67.74	85.70	103.71
3761	-49.28	-40.26	-22.25	-4.22	13.77	31.77	49.70	67.71	85.69	103.68
3765	-49.26	-40.24	-22.23	-4.20	13.78	31.78	49.73	67.72	95.70	103.70
88384	-49.24	-40.40	-22.51	4.51	13.49	31.51	49.49	67.55	85.58	103.62

The temperature sensors were mounted into Teledyne-Geotecn model 327 aspirated radiation shields (the most common in use on tall tower studies) (Fig. 13). These were then mounted at the sensing levels previously noted, on the tall tower (Fig. 3) and at the top of the 10 meter tower (Fig. 5). The shields incorporate three distinct shielding elements that protect the thermometer enclosure from the solar, atmospheric and terrestrial radiation. It is estimated by the manufacturer that the maximum absolute error in temperature is of the order of 0.1°C. In this study the error due to radiation is negligible. To allow good ventilation around the temperature sensor, the radiation shield is aspirated at all times.

Radiation Sensors

Measurements of incident ($K\downarrow$) and reflected ($K\uparrow$) solar radiative fluxes are made using two Eppley precision spectral pyranometer (model PSP). The response time and other characteristics of the sensor as provided by the manufacturer are tabulated in Table VIII. The relative sensitivity of the two sensors in the temperature range -20 to 40°C changes by 1.2 to 1.6%.

The two pyranometers were calibrated at 25°C by the National Atmospheric Radiation Centre, Atmospheric Environment Service using a specially designed radiation source integrating sphere. Fig. 14 shows the integrating sphere with the pyranometers placed in the lower compartment during calibration. The calibration factors for the short wave radiation were 8.64 and 8.93 microvolt/watt meter^2. The calibration in this case differed by 0.1 and 0.4% respectively from the manufacturer's calibration.

FIGURE 13: Temperature sensur during installation.

Table VIII. Specification of Eppley Precision Pyranometer Model PSP

Parameter	Specification
Sensitivity	9 μv per watt meter^{-2}
Temperature dependence	±1% over ambient temperature
Temperature range	-20 to +40°C
Linearity	±0.5%
Response time	1 s

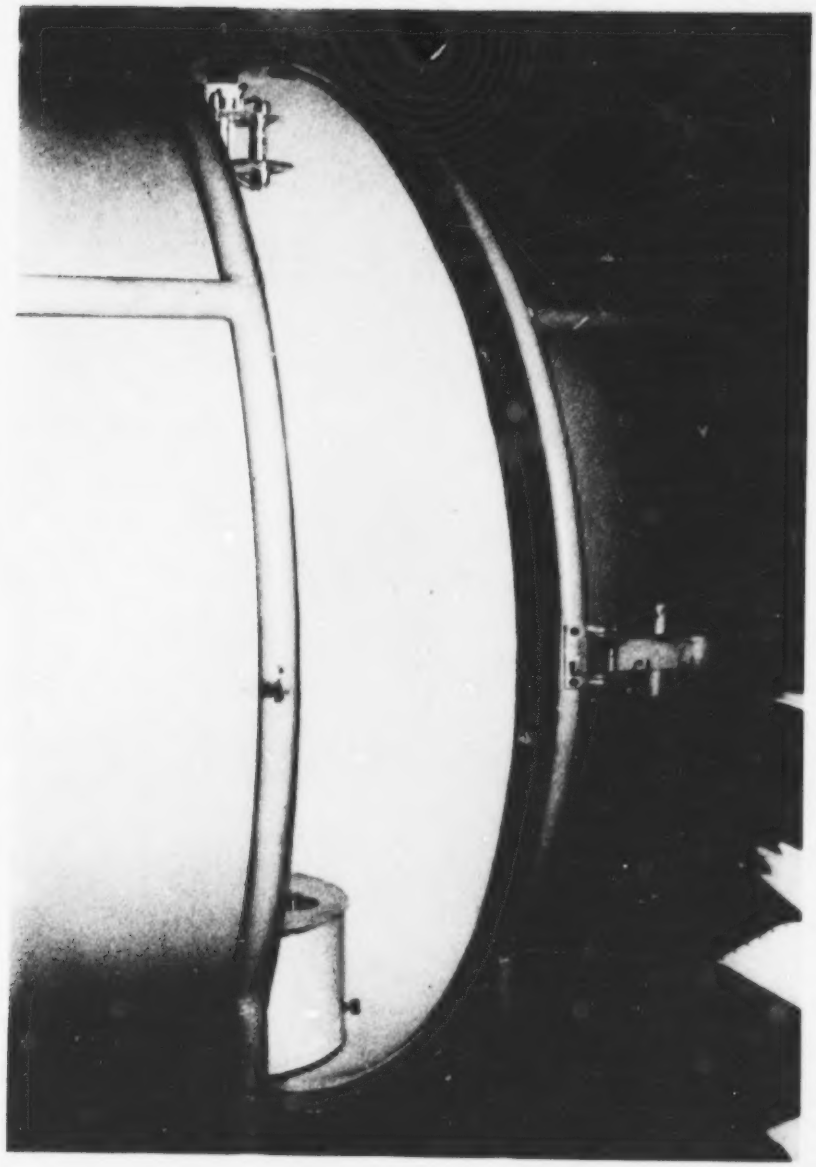

FIGURE 14: AES integrating sphere for calibrating the tower pyranometer.

After calibration, the two pyranometers were mounted on a specially designed aluminum frame. The frame was fastened to the 10 m tower. One instrument was facing upward and the second was facing downward. The downward facing pyranometer was approximately 1 m above the ground (Fig. 5). After installation the two instruments were levelled, using the spirit level that was mounted on the upward facing pyranometer. Once this had been done the pyranometer facing downward was automatically levelled. The orientation of the boom supporting the Eppley's is Eastwards. A shadow effect from the tower occurs with the sun in the west, however this is, by and large, the time of lowest sun angle (based on visual observations both summer and winter).

During the winter months, frost buildup on the Eppley sensors is a common occurrence. Also, snow may accumulate on the upward facing sensor. Under these circumstances, the output signal of the pyranometer does not represent a true condition.

The CBC technical staff have been instructed to clear away any accumulated snowfall, and to defrost the sensor bulbs using isopropyl II alcohol which has been supplied for this purpose.

Relative Humidity Sensor

The sensor used in this study was the Humidity and Temperature Indicator Type HM132 made by Vaisala Oy, Finland. The humidity sensor in this unit is the Vaisala HUMICAP 5832 which operates on the capacitive principle. It has a response time of about 5 seconds. It measures humidity within the range 0-100% relative humidity with an accuracy of ± 2%. The unit includes

also a temperature sensor which is a Pt 100 resistance element with a plastic coating and with 10 seconds time constant. It measures the temperature within the range -40 to +80°C, with an accuracy of ± 0.3°C.

Two humidity sensors were installed at the 2.5 meter and 15 meter levels of the main tall tower.

V Data

Data sets are taken each 30 seconds and averaged over a 10 minute mean. The data undergoes a preliminary analysis within the CR-7 and is outputted every 10 minutes to a set of two Panasonic cassette recorders. A hard copy printout is also made on a Hewlett-Packard model 82905-B printer with RS-232 option (Epson FX-80 comparable). One of the data cassettes and the hard copy printout are forwarded to AES, Downsview weekly by the CBC technical staff. The second tape - a back-up - is retained in Inuvik.

The on-line analysis of data within the CR-7, provides a calibrated 10 minute mean of wind direction, wind speed, temperature, vector wind direction and speed, relative humidity and solar radiation. Also a standard deviation is calculated for all components, save humidity and solar radiation (Table IX). This information is fed into the AS-6 computer in AES Headquarters, in Downsview, through a Campbell Scientific C-20 cassette interface. The data are then placed in an array, chronologically. Table IX shows a final array printout. The data are available for all NOGAP participants by contacting one of the authors.

TABLE IX
INUVIK RADIATION TOWER DATA -1985-
2METER

---------- JDAY=48 TIME=1500 ----------

R1	R2	R3
0.118000	0.0710000	0.0470000

---------- JDAY=48 TIME=1610 ----------

R1	R2	R3
0.118000	0.0660000	0.0520000

---------- JDAY=48 TIME=1520 ----------

R1	R2	R3
0.113000	0.0630000	0.0500000

---------- JDAY=48 TIME=1630 ----------

R1	R2	R3
0.108000	0.0610000	0.0470000

---------- JDAY=48 TIME=1540 ----------

R1	R2	R3
0.0980000	0.0560000	0.0420000

---------- JDAY=48 TIME=1650 ----------

R1	R2	R3
0.0870000	0.0500000	0.0370000

---------- JDAY=48 TIME=1700 ----------

R1	R2	R3
0.0710000	0.0410000	0.0300000

---------- JDAY=48 TIME=1710 ----------

R1	R2	R3
0.0540000	0.0320000	0.0220000

VI Data Analysis

The data obtained from the tower sensors provide reliable information on the wind and temperature regimes at the six sampling levels. Eighty-six percent of the data collected is available for use - some of the data (2 weeks worth) were lost in the mail at the initial phase of the study. A further four weeks of data were lost on tape due to faulty connections, however, the hard copy printout is available and data will be transcribed from this (by hand) into the AS-6 computer.

Some of the solar radiation data is unrecoverable or suspect due to accumulations of frost and/or snow on the sensors (notably the upper sensor). The relative humidity sensors(Humicaps) were installed but inoperative during the winter of 1985. Cold temperatures affected the ventilation motors, so the units were powered down until July 1985. They have worked continuously since then. Given this, the quantity of relative humidity data is considerably less than that for the other sensors.

For proper evaluation of the tower data, it is instructive at this point to compare the tower data with data obtained during the February field study. The results of the comparison are shown in Figures (15-17). It can be seen from the distribution of the points that the agreement is good, with a correlation coefficient (r) of 0.95 for the wind speed, 0.72 for the wind direction and 0.97 for the temperature.

In addition to the above comparison some anslyses of the tower data were made. The data sets that have been collected to date are not large enough to make conclusive statistical conclusions. By the end of the NOGAP program, the data collected from the towers will be sufficient.

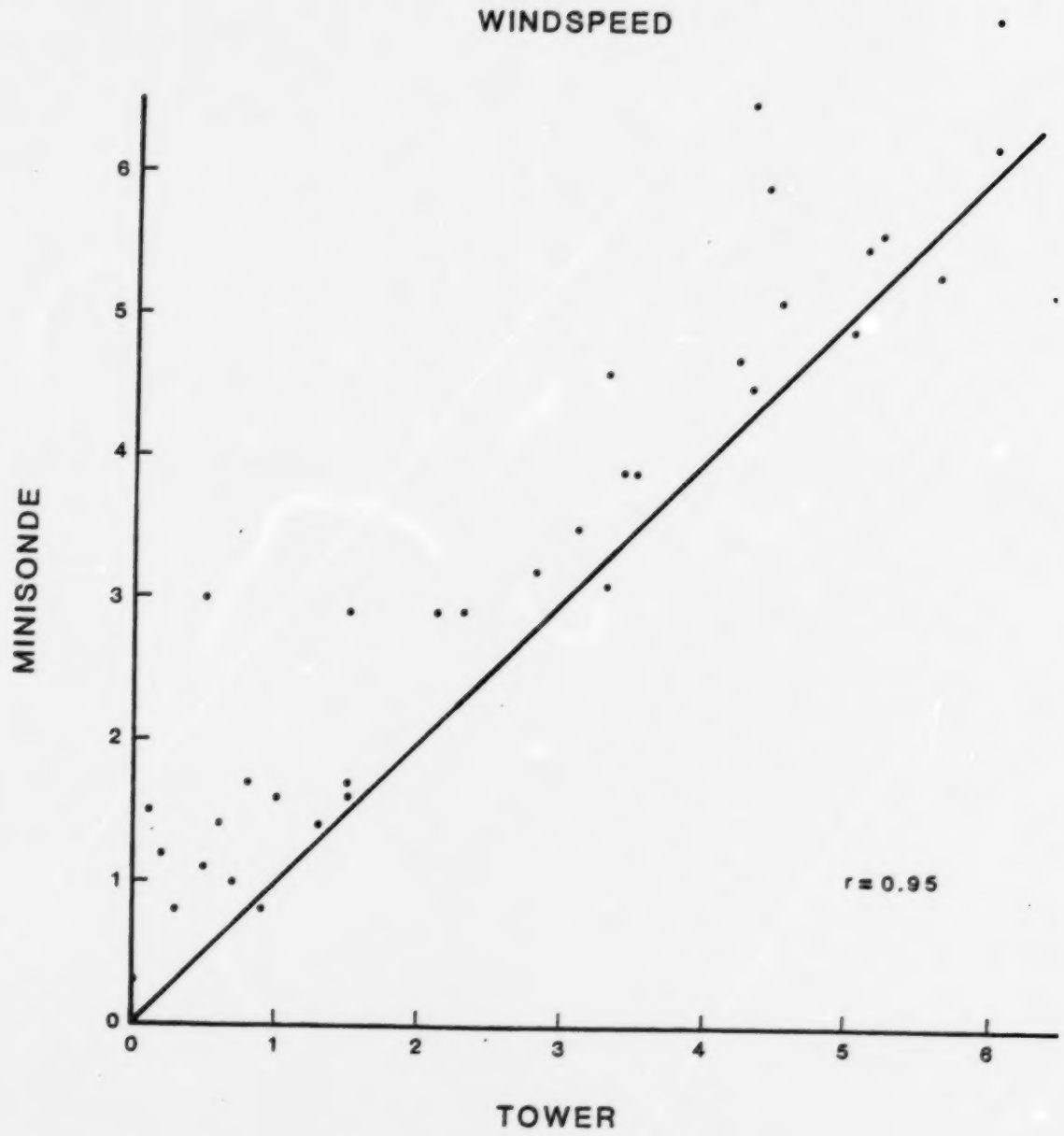

FIGURE 15: Comparison of minisonde wind speed versus tower wind speed.

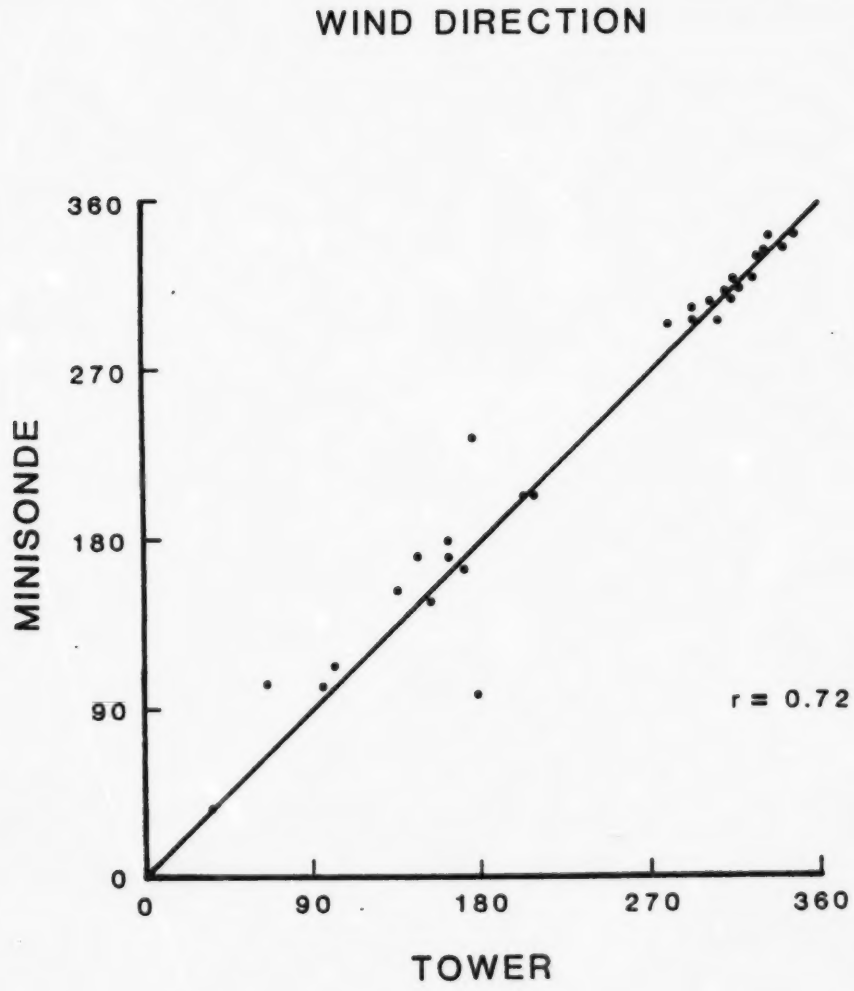

FIGURE 16: Comparison of minisonde wind direction versus tower wind direction.

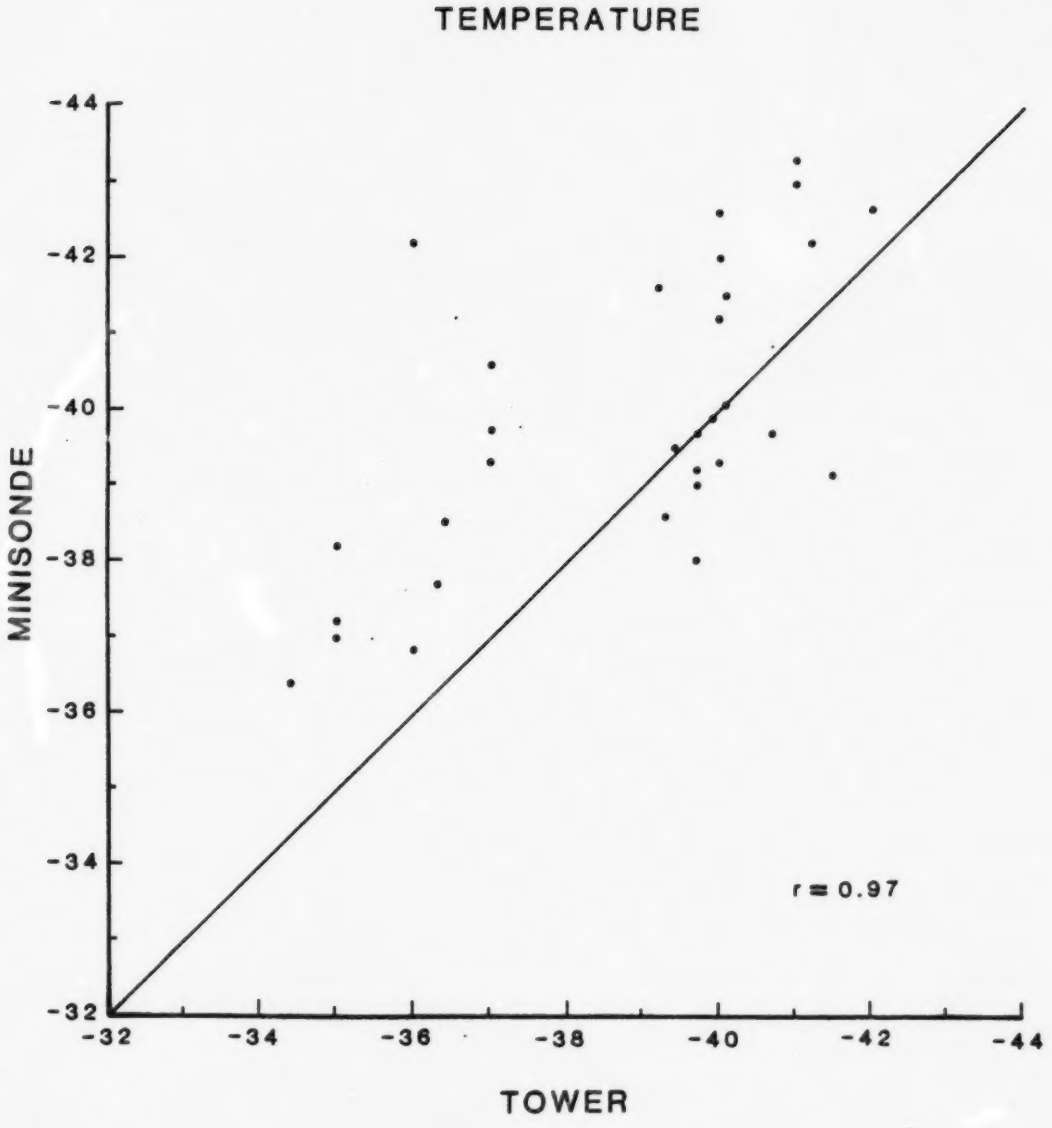

FIGURE 17: Comparison of minisonde air temperature versus tower air temperature.

Monthly averages of wind speed, wind direction and temperature were determined for the month of July to December (1985). Figure 18 shows the monthly average of the wind speed at all levels. Wind speeds ranged from 3.9 to 5.2 m/s. December had the lowest speed while November had the highest. At the 10 m level, the monthly change of wind speed was less than that at the 91 m level. For the month of November wind speeds at the 91 meter level were 47% higher than those at the 10 m level.

Wind speed distribution at the 91 m level is shown in Figure (19). There is a maximum in the 4-6 m/s range. Wind speed in this range occured 30% of the time, while those less than 4 m/s occurred about 35% of the time. For a higher range the frequency of occurrence is about 35%. It is interesting to note that wind speed greater than 12 m/s occurred about 1% of the time (at the 91 meter level).

An attempt was made to examine the diurnal cycle of the wind at the top level of the tower. Figure (20) illustrates the average diurnal cycle for the months of Feburary and July. The variations during February are not as pronounced as those during July. In July, a wind maxima occurs at 6 a.m. and at mightnight Mountain Daylight Time (M.D.T.) and a minimum at 9 a.m. The range of the variations is large ($\sim$ 30%). More data are needed however to confirm these changes.

Figure (21) shows the monthly average of the wind direction. For the months of August to December the wind direction was from the south. In July, however, the flow was southwesterly. December had the largest variations in wind direction from one level of the tower to the next (16°).

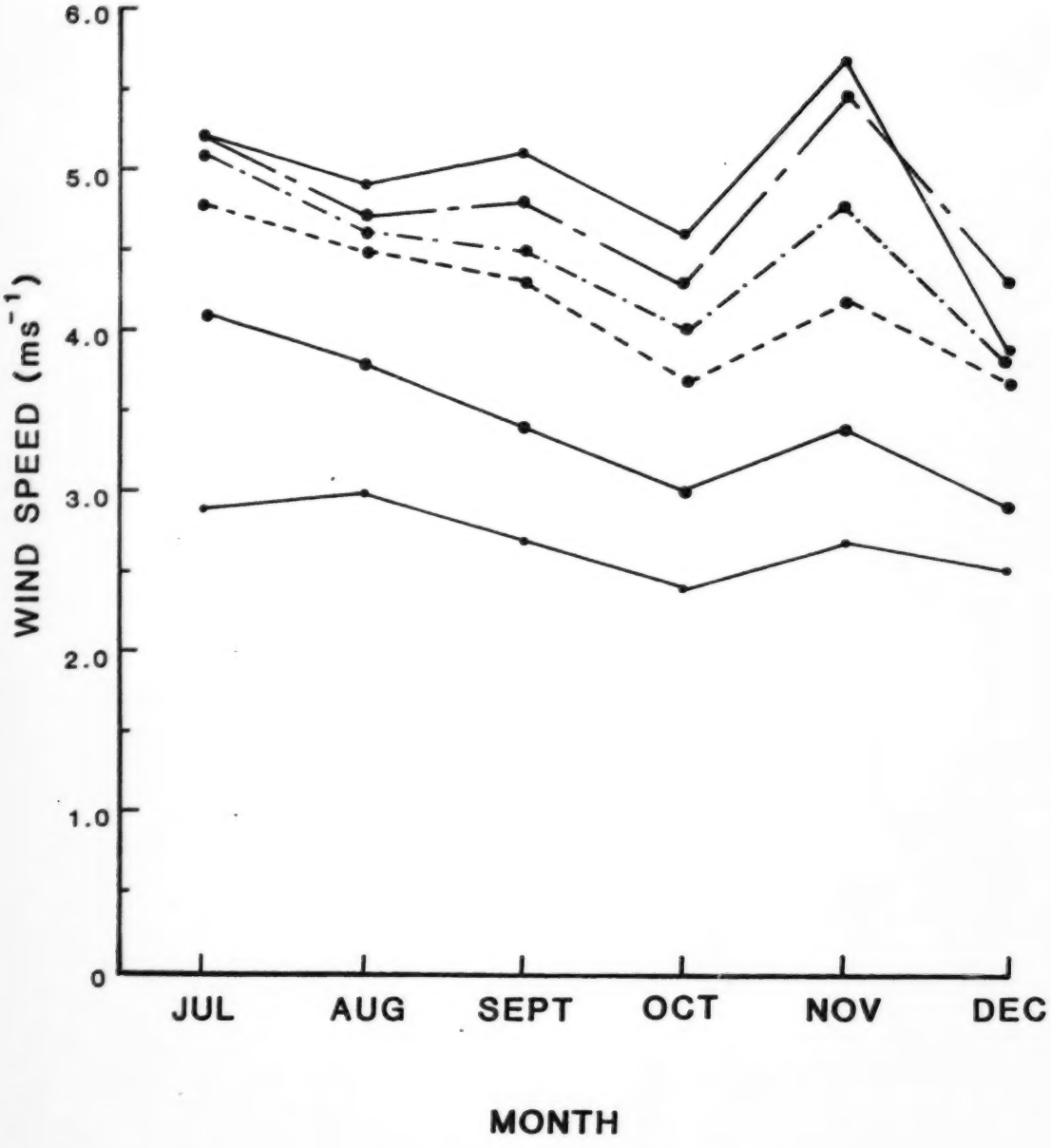

FIGURE 18: Monthly averages of wind speed at 6 levels of the tower.

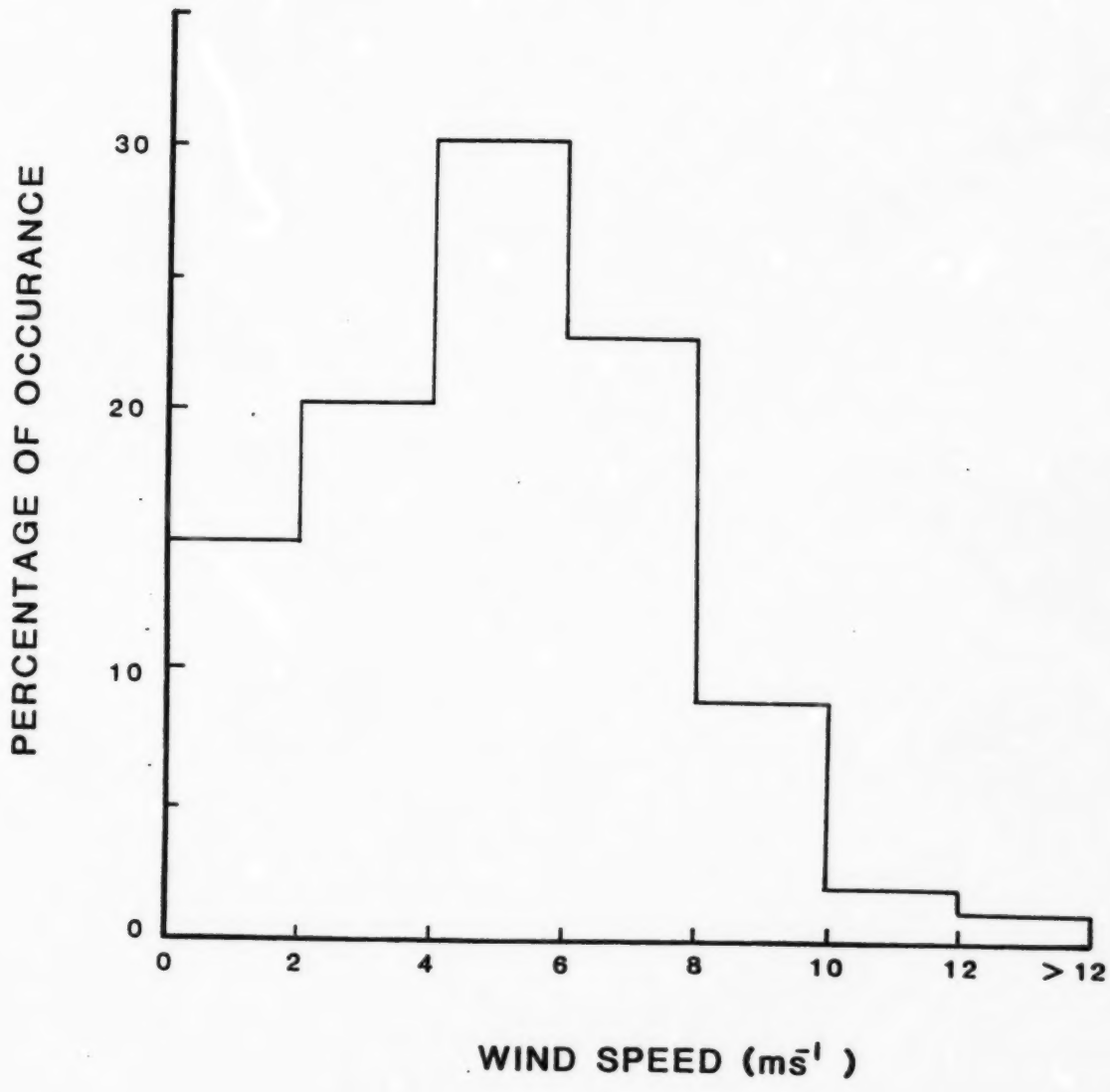

FIGURE 19: Wind speed distribution at 91 m level of the tower.

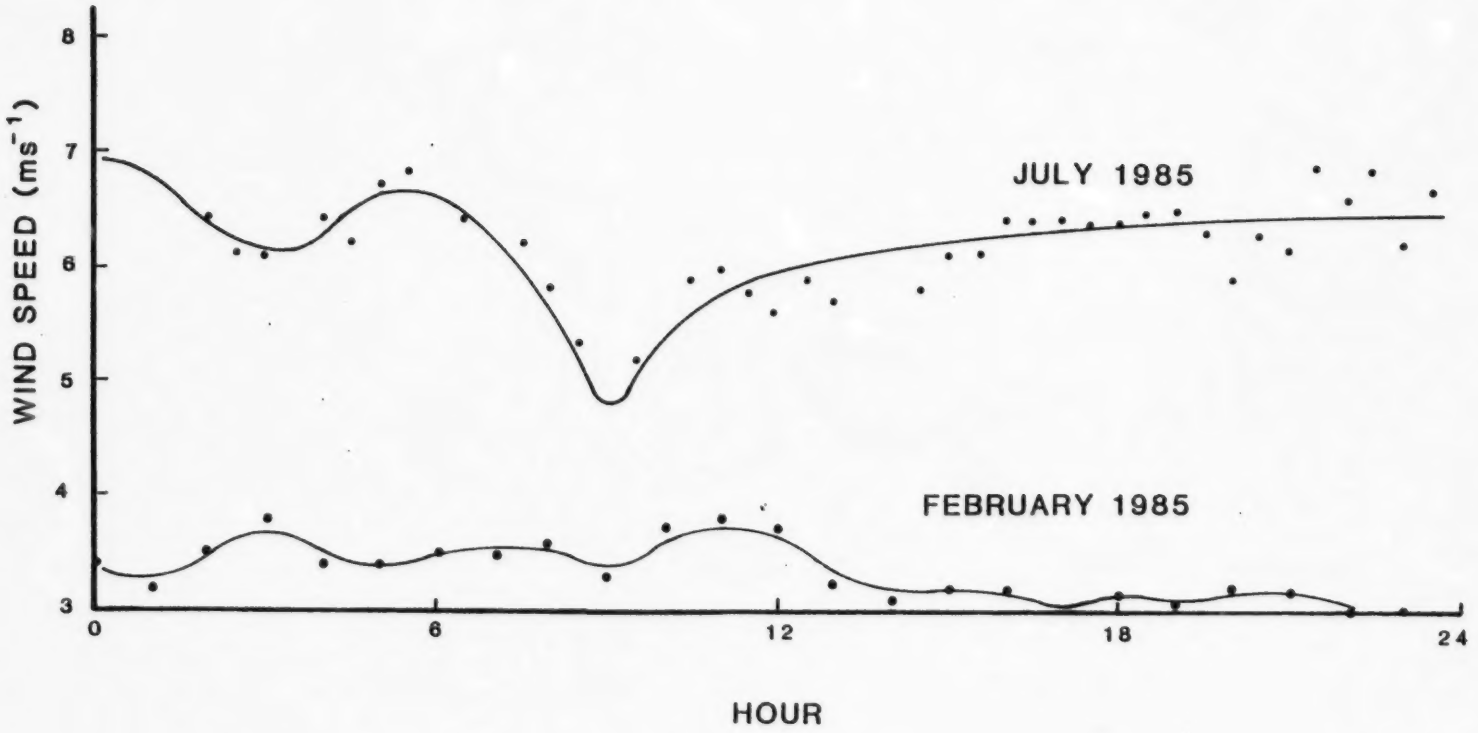

FIGURE 20. Diurnal cycle of wind speed for February and July, 1985.

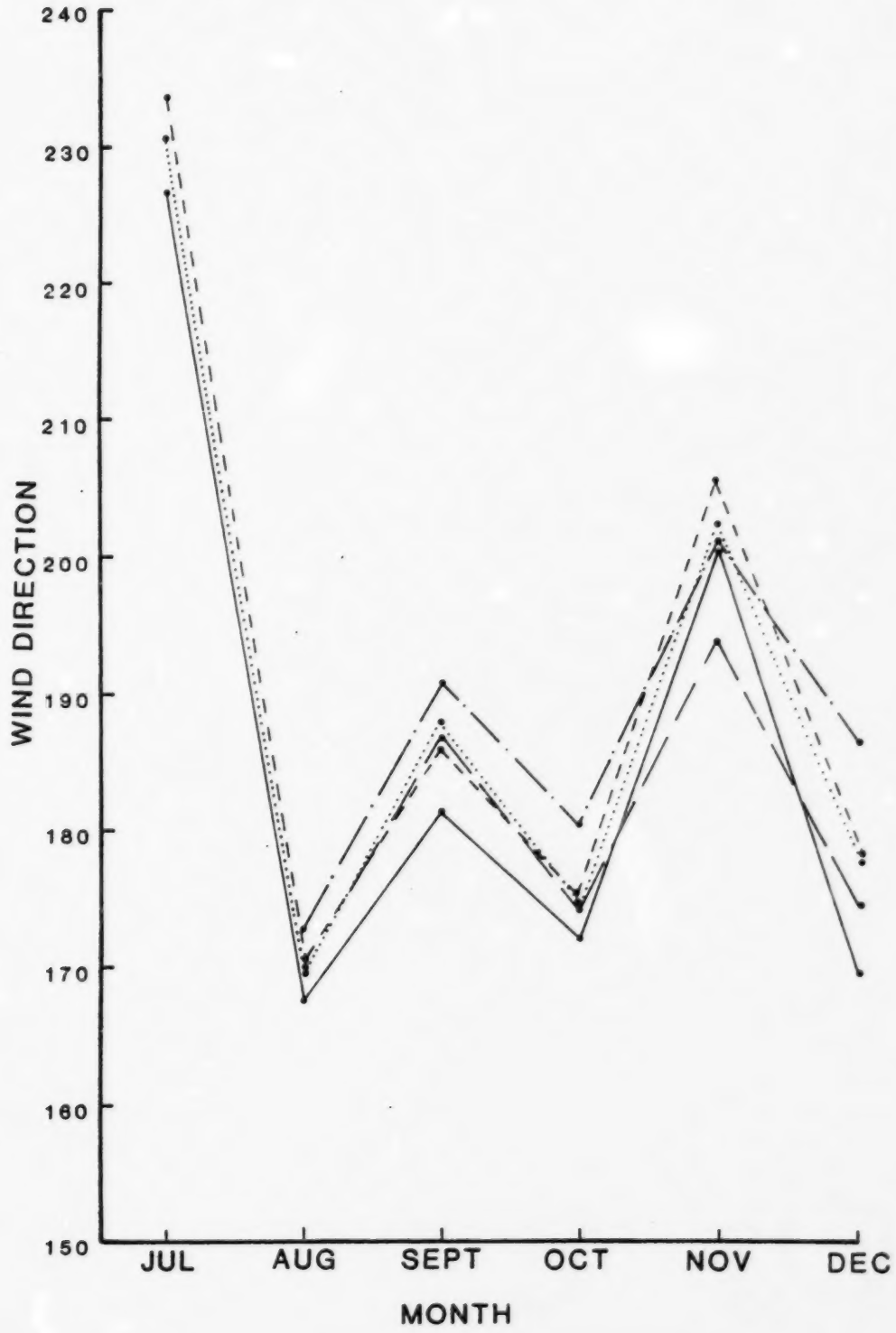

FIGURE 21: Average wind direction for the period August to December 1985.

The directional distribution of the wind at the 91 m level was examined and the result is shown in Figure (22) together with the long term data. The tower data agrees well with this long term trend. About 35% of the time the flow was from the northwest.

The stability of the atmosphere could be estimated using the σ_D (standard deviation of the horizontal wind direction) (see e.g. Gifford 1976). On this basis σ_D of the tower data at tne 91 m level for every day at 1200 MST was used to examine the stability. The data are summarized in Table X together with the conversion to the well known Pasquill-Gifford stability. In general and for the period that was covered by the data collected stability of the atmosphere ranged from neutral to very stable. 17.7% of the time the atmospnere was very unstable. These conclusions will be verified as soon as farther data have been collected.

The average temperature changes are displayed in Figure (23). August was the warmest month (+ 10°C) while December was the coldest (-20°C). The variation of the temperature from one level to the next of the tower was small. During November the change was about 1°C.

VII Concluding Remarks

Primarily this report dealt with sensing instrumentation of the Inuvik tall tower and their associated equipments and calibrations. All sensors used have been tested and conform to our sensitivity and accuracy requirements for field measurements. Wind and temperature sensors were calibrated in the laboratory before installation and the calibration agrees well with that of the manufacturer.

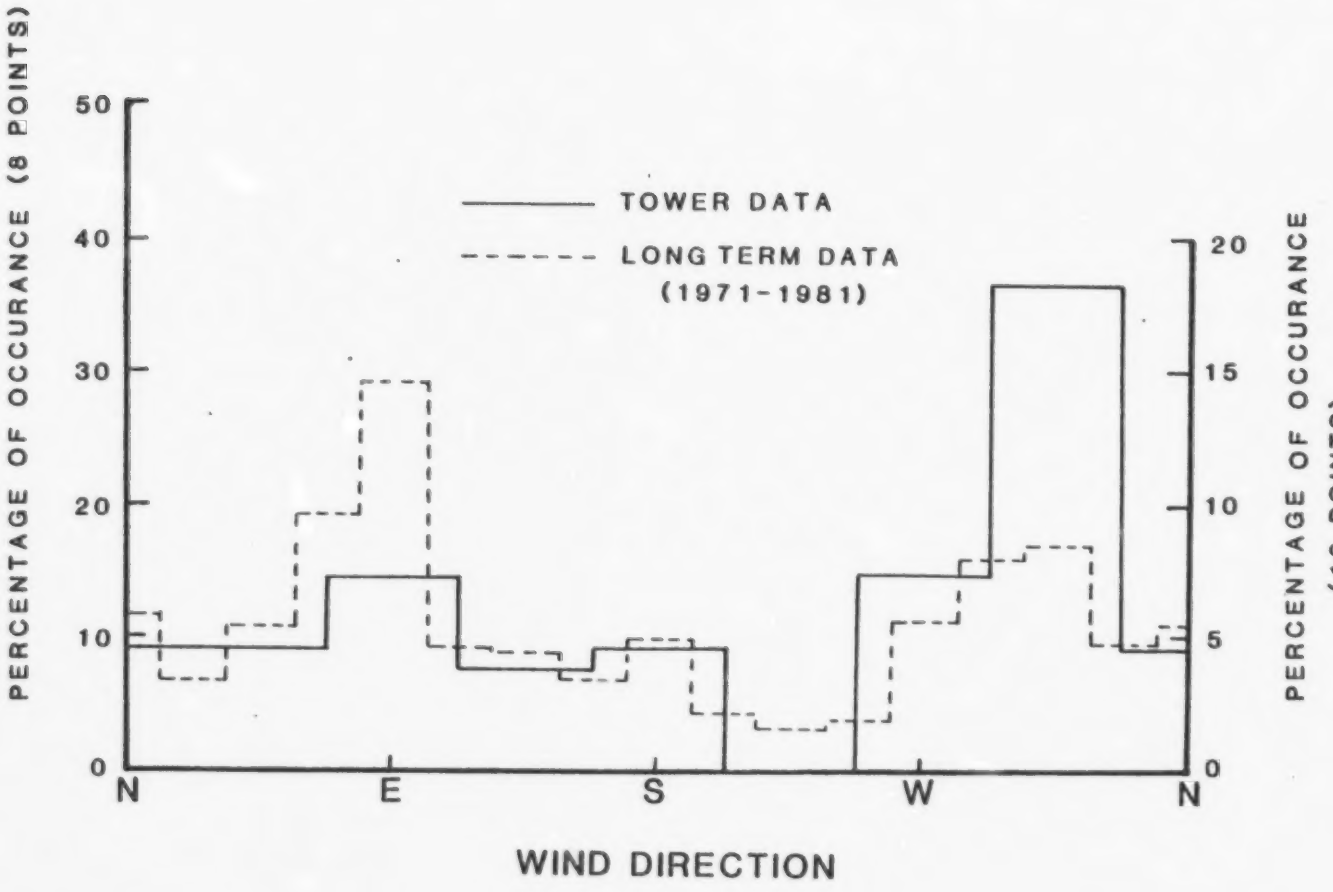

FIGURE 22: Wind direction distribution.

Table X. Distribution of Atmospheric Stability in the Inuvik Area

STABILITY	% OF OCCURRENCE
Very unstable (A)	17.7
Moderately unstable (B)	1.6
Slightly unstable (C)	1.6
Neutral (D)	25.8
Moderately stable (E)	32.3
Very stable (F)	21.0

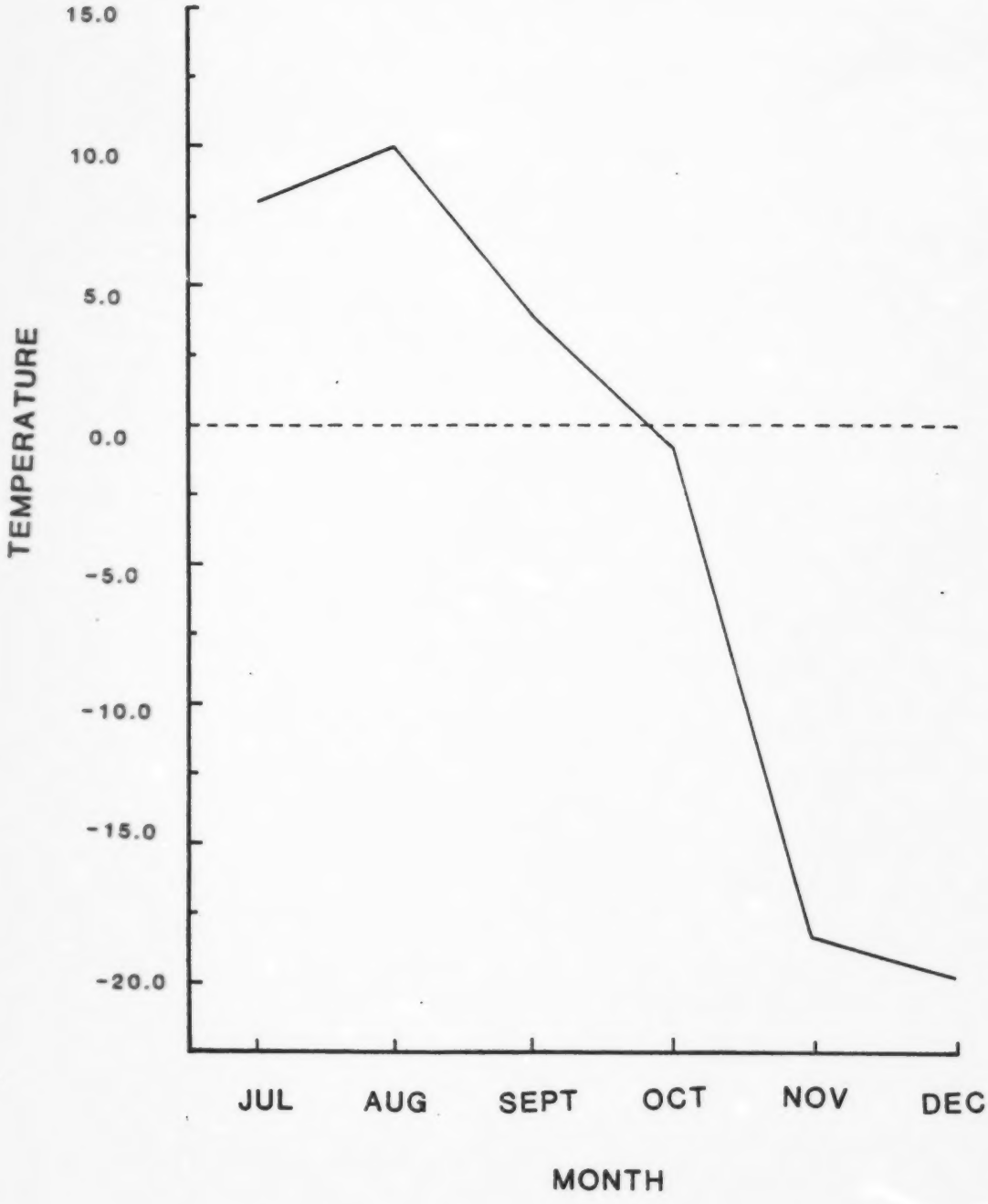

FIGURE 23: Average temperature change with time.

Although the Inuvik meteorological tower was established for NOGAP project C.19, the data obtained have considerable application in other areas (e.g. structure design, oil drilling, oil spill, short range forecast and energy budget).

For the purposes of Project C.19, the data as stored is a data base upon which future dispersion models will be constructed. Aside from specialized analysis and graphical productions, the data are considered to be complete and finished. Further analysis, manipulation or reduction will be left at the discretion of all users.

Routine updates will be published advising all users as to the status and availability of data contained in the data base. This will appear, more or less, in the form of a bulletin informing users of the quantity of data on mass storage in the AS-6.

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